Temperature and Magnetic Field Dependencies of Condon Domain Phase in Lifschitz-Kosevich-Shoenberg Approximation

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The temperature and magnetic field behavior of non-uniform diamagnetic phase of strongly correlated electron gas at the conditions of dHvA effect is analyzed. It is shown, that in the framework of Lifschitz-Kosevich-Shoenberg approximation the magnetic induction splitting, as well as the range of existence of Condon domains, are characterized by strong dependencies on temperature, magnetic field and impurities of the sample.

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I. INTRODUCTION

Oscillations of the thermodynamic quantities of electron gas in magnetic field are the result of the oscillations of the density of states when successive Landau levels sweep through the Fermi level [1]. At high magnetic field and low temperature the instability of strongly correlated electron gas due to magnetic interaction between electrons results in diamagnetic phase transition (DPT) [2] with formation of Condon domain (CD) structure, which is extensively studied, both theoretically and experimentally [3]-[16]. Magnetic interaction of strongly correlated electron gas results in non-linear dependence of local diamagnetic moments on external magnetic field and temperature [9] and gives rise such an exotic phenomenon as diamagnetic hysteresis [11], [14].

Recent progress in experiments on observation of CD structure in Ag [5] and Be [11] provides a natural stimulus towards a more detailed understanding of the properties of strongly correlated electron gas in the conditions of dHvA effect.

Although the theoretical aspects of the CD formation have been recently reviewed [8], some important questions concerning the DPT and non-uniform phase of strongly correlated electron gas are still open. In particular, the detailed theoretical investigation of the influence of the temperature T, magnetic field $\mu_0 H$ and impurities of the sample on such important characteristics of the non-uniform diamagnetic phase, as the range of existence of the CD structure and magnetic induction splitting, is still lacking.

We present the theoretical investigation of the temperature and magnetic field behavior of the CD phase in the framework of Lifshitz-Kosevich-Shoenberg (LKS) approximation [1], [2] and compare our results with available data on investigation of CDs in Ag [4],[5].

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II. MODEL

The oscillator part of the thermodynamic potential density in the LKS approximation [2] can be written in reduced form with taking into account the shape sample effects:

$$\Omega = \frac{1}{4\pi k^2}\left[a\cos b + \frac{1}{2}a^2(1-n)\sin^2 b\right], \qquad (1)$$

where $b = k(B-\mu_0 H) = k[h_{ex} + 4\pi(1-n)M] = x + (1-n)y$, $\mu_0 H$ is the magnetic field inside the material $k = 2\pi F/(\mu_0 H)^2$, F is the fundamental oscillation frequency), $h_{ex} = H_{ex} - H$ is the small increment of the magnetic field H and the external magnetic field H_{ex}, n is the demagnetization factor. The validity of thermodynamic potential density (1) is restricted by applicability to homogeneous phase only, where the conception of demagnetization coefficient n is justified [9]. In the conditions of strong magnetic interaction, when

$$a\left(\mu_0 H, T, T_D\right) \geq 1, \qquad (2)$$

a state of lower thermodynamic potential is achieved over part of dHvA oscillation cycle by the formation of CD structure. The usually observed diamagnetic domain structure is of stripe-domain type [2],[5]. In the domain state, when the reduced amplitude of dHvA oscillations satisfies to the condition (2), the demagnetization factor n is replaced by the coefficient α [9], which depends on magnetic field, temperature, impurities and geometry of the sample.

The equation $a(\mu_0 H, T, T_D) = 1$ defines the critical surface in three dimensions $\mu_0 H - T - T_D$. Above this surface the uniform diamagnetic phase exists, but below it, the CD phase appears in the part of the period of dHvA oscillations.

In the non-uniform phase, when the condition (2) is fulfilled, the metastable states, formed by magnetic field

h, are determined by

$$\frac{\partial\Omega}{\partial x} = 0, \quad \frac{\partial^2\Omega}{\partial x^2} > 0, \tag{3}$$

identifying two local minima of the thermodynamic potential (1). The diamagnetic moments $y_\pm$ corresponding to these minima, being the functions of magnetic field increment x and reduced amplitude of the dHvA oscillations $a = a(\mu_0 H, T, T_D)$ [9], are characterized by the strong dependence on magnetic field, temperature and impurity of the sample and contribute to the magnetic induction splitting $\delta b = y_+ - y_-$ between two adjacent domains. The average magnetic induction splitting can be defined as the magnetic induction splitting at the center of the period of dHvA oscillations:

$$\delta b(x; a) \approx \delta b(0; a) = y_+(0; a) - y_-(0; a). \tag{4}$$

In this case the magnetic induction splitting δb is calculated due to

$$\delta b = 2a \sin\frac{\delta b}{2}. \tag{5}$$

In limit $a \to 1 + 0^+$, e.g. in the nearest vicinity of the point of DPT, from the Eq. (5) one can obtain the expression for magnetization $y_\pm = \pm\sqrt{[6(1-1/a)]}$ [8]. According to Eq. (5) magnetic induction splitting $\delta b = \delta b(a)$ has strong dependencies on magnetic field $\mu_0 H$, temperature T and Dingle temperature T_D through the reduced amplitude of dHvA oscillations $a = a(\mu_0 H, T, T_D)$.

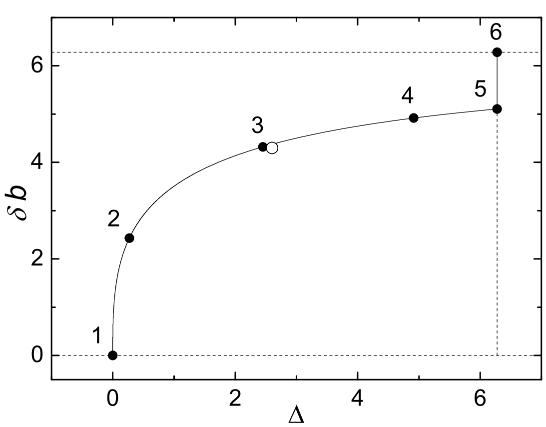

FIG. 1: The magnetic induction splitting δb as a function of the range of existence of non-uniform phase Δ. Closed circles show the different values of reduced amplitude of dHvA oscillations a: 1 - $a = 1$, 2 - $a = 1.3$, 3 - $a = 2.6$, 4 - $a = 3.9$, 5 - $a = 4.6$, 2 - $a \to \infty$. Both variables $0 \leq \delta b \leq 2\pi$ and $0 \leq \Delta \leq 2\pi$ are restricted by the period of the oscillations (2π in reduced units), which is shown by dash lines. The straight line between points 5 and 6 corresponds to slow increase of induction splitting δb with increase of a in the interval $a \in [4.6, \infty)$, when Δ has reached its maximum value $\Delta = 2\pi$. The open circle corresponds to the data [4].

The range of existence of the CD structure Δ in every period of dHvA oscillations can be estimated by consideration of the instability points, or inflection points, where the next two conditions must simultaneously hold

$$\frac{\partial\Omega}{\partial x} = 0, \quad \frac{\partial^2\Omega}{\partial x^2} = 0. \tag{6}$$

Using the Eqs. (6) one can obtain

$$\Delta = 2(\sqrt{a^2-1} - \cos^{-1}\frac{1}{a}). \tag{7}$$

From Eq. (7) it follows that the range of existence of the CD structure is also dependent on magnetic field $\mu_0 H$, temperature T and Dingle temperature T_D.

For proper calculation of the reduced amplitude of the dHvA oscillations a and investigation of the temperature and magnetic field characteristics of CD phase, the correct topology of Fermi surface has to be taken into account.

In case of ellipsoidal Fermi surface, the temperature and field dependence of the reduced amplitude of dHvA oscillations a is defined by [2],[8]

$$a = a_0(\mu_0 H)\frac{\lambda(\mu_0 H, T)}{\sinh\lambda(\mu_0 H, T)}\exp\left[-\lambda(\mu_0 H, T_D)\right], \tag{8}$$

where

$$\lambda(\mu_0 H, T) = \frac{2\pi^2 k_B m_c c T}{e\hbar\mu_0 H}, \tag{9}$$

m_c is the cyclotron mass, k_B is the Boltzmann constant, e is the absolute value of the electron charge, c is the light velocity, $\hbar$ is the Planck constant, and $T_D = \hbar/2\pi k_B \tau$ is the Dingle temperature, which is inversely proportional to the scattering lifetime τ of the conduction electrons.

The limiting amplitude

$$a_0 \equiv a(T \to 0, T_D \to 0) = \left(\frac{H}{H_m}\right)^{3/2} \tag{10}$$

is the combination of temperature-independent factors in the Lifschitz-Kosevich formula [1], and

$$\mu_0 H_m = (10.4\eta\epsilon_F^2)^{2/3} \tag{11}$$

is the limiting field [8] above which DPT does not occur at any temperature T, ϵ_F is Fermi energy in eV, $\eta = m_c/m$ and m electron mass. The validity of the LKS approximation and, consequently, the expression for reduced amplitude of the dHvA oscillations a (8) is restricted by the application to the spherical (or almost spherical) Fermi surface sheets, which is the case of noble metals [2]. The recent experimental data on observation

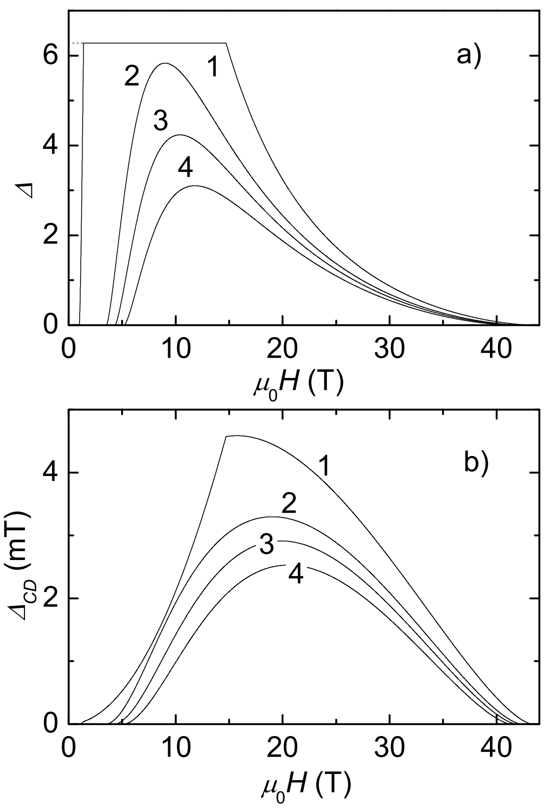

FIG. 2: Magnetic field dependence of the reduced range of existence of non-uniform phase Δ (a) and corresponding measured range Δ_{CD} (a) in silver for $T_D = 0.1K$ and four different temperatures: 1 - $T = 1K$, 2 - $T = 1.5K$, 3 - $T = 1.75K$, 4 - $T = 2K$. The straight horizontal line at (a) corresponds to the maximum value of $\Delta = 2\pi$. This line transforms into second power of magnetic field dependence of $\Delta_{CD} = \Delta/k$ at the same interval of magnetic field (b). At $T = 1K$ Δ_{CD} reaches its maximum value at $\mu_0 H \approx 15T$.

of CD structure in Ag [11], [15] by measurement of the amplitude of the third harmonic of the *ac* susceptibility reveals the possibility to construct the phase diagram. As it was expected, the measured phase diagrams for Ag [15] are in a good agreement with the calculated in the framework of LKS formalism phase diagrams, justifying the applicability of the Eq. (8) for belly oscillations in Ag.

III. RESULTS AND DISCUSSIONS

When the condition (2) is fulfilled, the sample is divided into domains with up and down magnetization. Both the magnetic induction splitting defined in explicit form by the Eq. (5) and the range of existence of CDs Eq. (7) are the functions of reduced amplitude of the dHvA oscillations and cannot be considered as independent functions at wide range of applied magnetic field and temperature. Mathematically, the Eqs. (2),(5) define the function $\delta b = \delta b(\Delta)$ in parametric form with the parameter $a \in [1,\ 4.6]$ (Fig. 1). At $a = 4.6$ the reduced range of existence of CD structure spreads through all period of the dHvA oscillations and remains constant at further increase of a.

The results of numerical calculations (Fig. 1) show rapid increase of magnetic induction δb with increase of reduced amplitude a in the vicinity of the point of DPT with slowing down of this increase at $a \in [2,\ 4.6]$. Contrary to it, the range of existence of the CD structure Δ is characterized by slow increase near the DPT point and rapid increase at the biggest values of a till its full value $\Delta = 2\pi$ at $a = 4.6$. Thus, $\delta b = 2.43 >> \Delta = 0.27$ at $a = 1.3$. At the interval $a \in [4.6, \infty]$ the function δb increases slowly with increase of a, while the range of existence of CDs remains constant $\Delta = 2\pi$. In famous experiment on observation of CD structure in Ag by NMR [4] the value of a was found to be about 2.6, which is consistent with the value of a, calculated from Eq. (8) at the conditions of the experiment: $\mu_0 H = 9T$, $T = 1.4K$ and

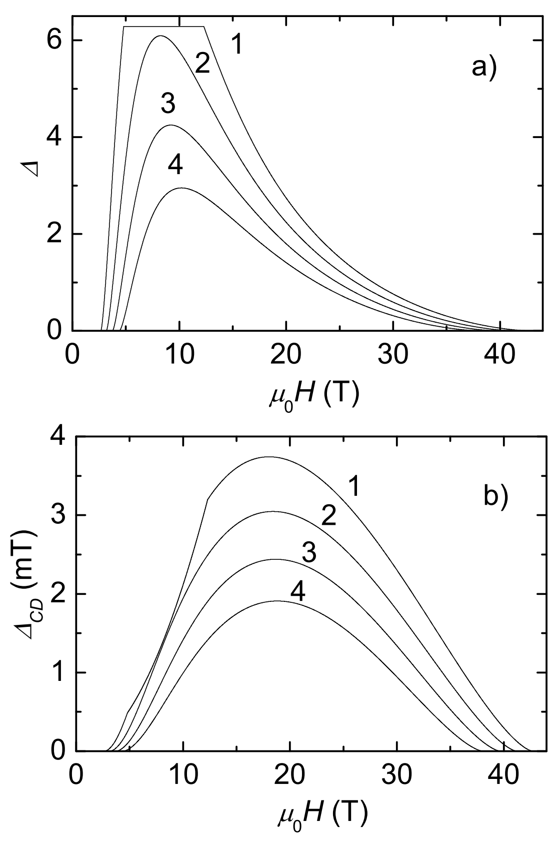

FIG. 3: Magnetic field dependence of the reduced range of existence of non-uniform phase Δ (a) and corresponding measured range Δ_{CD} (a) in silver for $T = 1.2K$ and four different Dingle temperatures: 1 - $T_D = 0.1K$, 2 - $T_D = 0.25K$, 3 - $T_D = 0.4K$, 4 - $T_D = 0.55K$. Similar to the Fig. 2 the straight horizontal line at (a) corresponds to the maximum value of $\Delta = 2\pi$. This line transforms into second power of magnetic field dependence of $\Delta_{CD} = \Delta/k$ at the same interval of magnetic field in (b). Δ_{CD} reaches its maximum value at $\mu_0 H \approx 20T$.

$T_D = 0.8K$. Using the reported values of the dHvA period $\Delta H \approx 17G$, $\delta B/\mu_0 \approx 12G$ and evaluating the range of existence of the CD structure as $\Delta_{CD} \approx 7G$, one can estimate $\delta b = 2\pi\delta B/\mu_0\Delta H \approx 4.3$ and $\Delta = k\Delta_{CD} \approx 2.6$. These values are very close to $\delta b = 4.4$ and $\Delta = 2.5$, calculated from Eqs. (4) and (7).

Due to the bell-like shape of the diamagnetic phase diagrams $T = T(\mu_0 H, T_D)$ (see, e. g. [8]) there is one critical temperature T_c at given magnetic field and two critical values of magnetic field $H_\mp$ ($H_- < H_+$) at given temperature. Another possibility for realization of the DPT is related to the concentration of impurities in the sample, which influence on the amplitude of the dHvA oscillations through the scattering τ of conduction electron.

Near the point of DPT $a \to 1 + 0^+$ ($T \to T_c + 0^-$, or $H \to H_\mp + 0^\pm$, or $T_D \to T_{D,c} + 0^-$) the temperature and magnetic field dependencies of magnetic induction δb can be represented as follows:

$$\delta b = \begin{cases} 2[6\lambda_c L(\lambda_c)]^{1/2}\Big(\dfrac{T_c - T}{T_c}\Big)^{1/2}, & T \to T_c + 0^- \\ 2(6\lambda_{D,c})^{1/2}\Big(\dfrac{T_{D,c} - T_D}{T_{D,c}}\Big)^{1/2}, & T_D \to T_{D,c} + 0^- \\ 2(6\alpha_\mp)^{1/2}\Big(\pm\dfrac{H - H_\mp}{H_\mp}\Big)^{1/2}, & H \to H_\mp + 0^\pm \end{cases} \tag{12}$$

where $L(t) = \coth t - 1/t$ is Langevin function and

$$\alpha_\mp = \pm\big[-\frac{3}{2} + \lambda_\mp L(\lambda_\mp) - \lambda_\mp^{(D)}\big]. \tag{13}$$

Here, $\lambda_c = \lambda(\mu_0 H, T_c)$, $\lambda_{D,c} = \lambda(\mu_0 H, T_{D,c})$, $\lambda_\mp = \lambda(\mu_0 H_\mp, T)$, $\lambda_\mp^{(D)} = \lambda(\mu_0 H_\mp, T_D)$. It can be shown that near the point of DPT the range of existence of CD structure Δ is related to the magnetic induction splitting δb according to

$$\Delta = \frac{1}{36}(\delta b)^3. \tag{14}$$

It follows from Eqs. (12) and (14) that the parameters of the CD phase are characterized by the critical behavior near the DPT. The temperature and magnetic field dependencies of the order parameter δb (12) can result in existence of soft mode. The possibility of softening of the orbital magnon mode was studied in [16].

In general case the temperature and magnetic field characteristics of CD structure can be calculated from Eqs. (4) and (7) with taking into account the Eq. (8) for reduced amplitude of the oscillations. To illustrate the behavior of the non-uniform diamagnetic phase, we calculated the temperature and magnetic field dependencies of the range of existence of CDs Δ and magnetic induction splitting δb for Ag, where the domains were observed [5] and the DPT diagrams were confirmed experimentally [15].

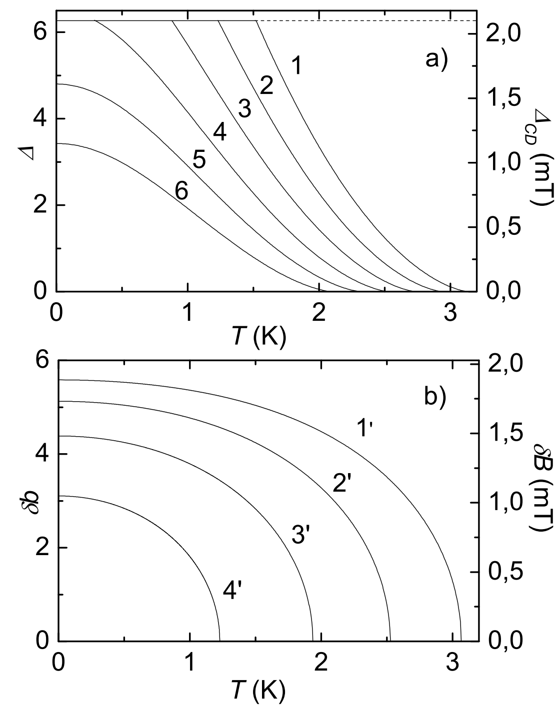

FIG. 4: (a) Temperature dependence of the range of existence of CD phase for six different Dingle temperatures: 1 - $T_D = 0.1K$, 2 - $T_D = 0.25K$, 3 - $T_D = 0.4K$, 4 - $T_D = 0.55K$, 5 - $T_D = 0.7K$ and 6 - $T_D = 0.85K$. (b) Temperature dependence of the magnetic induction splitting due to CDs for four different Dingle temperatures: $1'$ - $T_D = 0.1K$, $2'$ - $T_D = 0.5K$, $3'$ - $T_D = 0.9K$ and $4'$ - $T_D = 1.3K$. The strait horizontal line at (a) corresponds to the maximum value of $\Delta = 2\pi$.

The measured, or absolute, values of the range of existence of CD structure Δ_{CD} and magnetic induction splitting ΔB are defined as follows

$$\Delta_{CD} = \frac{\Delta}{k} = \Delta\frac{(\mu_0 H)^2}{2\pi F}, \tag{15}$$

$$\Delta B = \frac{\delta b}{k} = \delta b\frac{(\mu_0 H)^2}{2\pi F}, \tag{16}$$

The results of numerical calculation of the temperature and magnetic field dependencies of the parameters of the CD structure, Δ Eq. (7) and δb Eq. (5), are illustrated in Figs. 2-6.

Fig. 2 shows the magnetic field dependencies of the range of existence of CD structure in Ag at constant Dingle temperature $T_D = 0.1K$ and several temperatures: $T = 1K$, $T = 1.5K$, $T = 1.75K$, and $T = 2K$. The straight horizontal line in the graphical representation of the function $\Delta = \Delta(\mu_0 H)$ at $T_D = 0.1K$ (Fig. 2 (a), curve 1) corresponds to the full value of reduced range $\Delta = 2\pi$ with the amplitude of oscillations $a \geq 4.6$ (compare with the straight line 5 - 6, Fig. 1). Corresponding

measured, or absolute, range of non-uniform phase existence Δ_{CD} (15) is characterized by the second power field behavior at the same applied field interval (Fig. 2). The function Δ_{CD} has maximums at the middle range of applied field $\mu_0 H \in (15,\ 25T)$ and decreases with increase of the impurity of the sample.

In Fig. 3 the range of existence on CDs is shown as a function of magnetic field for $T = 1.2K$ and four different Dingle temperatures: $T_D = 0.1K$, $T_D = 0.25K$, $T_D = 0.4K$, and $T = 0.55K$. The growth of Dingle temperature results in decrease of the range of the non-uniform phase. Similar to Fig. 2, the straight horizontal line in Fig. 3(a) corresponds to the maximum of reduced range Δ, which results in quadratic increase of the absolute range of CD existence Δ_{CD} (15).

The temperature dependencies of the range of existence of CDs Δ (7) (Δ_{CD} (15)) and magnetic induction splitting δb (5) (δB (16)) at $\mu_0 H = 10T$ and different Dingle temperatures T_D are illustrated in Fig. 4. At the temperature interval $T \sim 0 - 1.5K$ for $T_D = 0.1K$ (curve 1 (a)) the range of CD existence Δ spreads over all period of dHvA oscillations, reaching its maximum possible value. Near the point of diamagnetic phase transition, when $a \to 1 + 0^+$ the parameter of the order δb exhibits critical behavior in accordance with Eq. (12). It results in softening of orbital mode. The last circumstance is important for experimental observation of the DPT point and constructing the phase diagrams $\mu_0 H - T - T_D$ by measuring the temperature dependence of parameter of order $\Delta B = \Delta B(T)$. The increase of the Dingle temperature T_D results in decrease of the range δ (Fig. 4(a)) and splitting δb (Fig. 4(b)).

The magnetic field dependencies of induction splitting δb (δB) are shown in Fig. (5) for five different temperatures and in Fig. 6 for four different Dingle temperatures. The maximum values of absolute induction splitting (δB) are shifted into high-field range $\mu_0 H \sim 25 - 40T$.

The magnetic induction splitting due to CD structure changes the distribution of magnetic field in vacuum above the surface of the sample. The possibility of detection of these changes by means of Hall probe spectroscopy and mapping of CD structure is discussed in [12], [13] and realized in [5], [15]. It was found [12], [13] for the plate-like sample in applied magnetic field along the normal to the surface $\boldsymbol{H} \parallel \boldsymbol{Z}$ with periodic domain structure along the Y-axis , that the normal component of magnetic field H_n is described by the following periodic function of Y with the period $2D$ equal to the period of CD structure :

$$H_n = \frac{\delta B}{\pi \mu_0} \tan^{-1} \frac{\cos(\pi Y/D)}{\sinh(\pi Z/D)}. \qquad (17)$$

The measured value by method of Hall probes is the maximum splitting of the normal components of non-uniform magnetic field above two neighboring domains δH_n, e. g. the maximum difference between two values, $H_n^{\uparrow}$ and $H_n^{\downarrow}$, of normal component of magnetic field

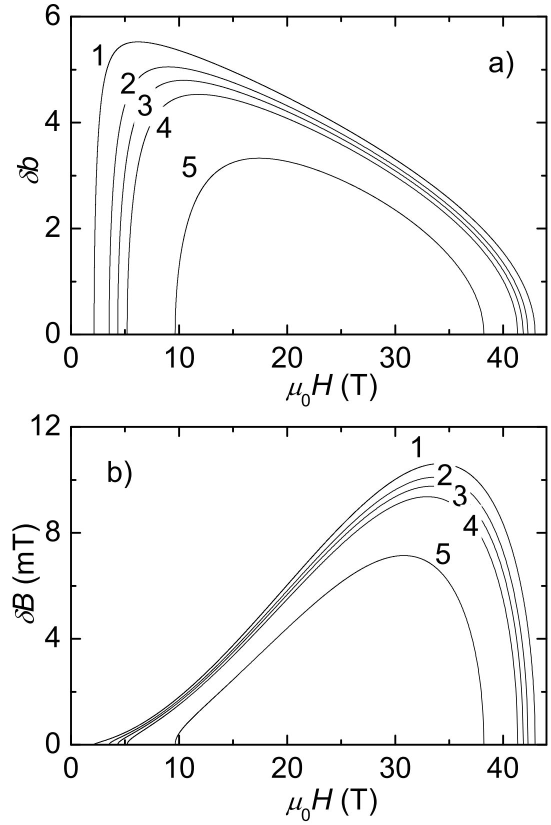

FIG. 5: Magnetic field dependence of the reduced induction splitting δb (a), caused by two adjacent domains, and corresponding measured value δB (b) in silver for $T_D = 0.1K$ and five different temperatures: 1 - $T = 1K$, 2 - $T = 1.5K$, 3 - $T = 1.75K$, 4 - $T = 2K$, and 5 - $T = 3K$. The second power law dependence of the period of the dHvA oscillations on the applied magnetic field shifts the maximum values of measured characteristics to the high-field range.

Eq. (17) caused by magnetic induction splitting δB inside the sample

$$\delta H_n \equiv H_n^{\uparrow} - H_n^{\downarrow} = \frac{2}{\pi} \frac{\delta B}{\mu_0} \tan^{-1} \frac{1}{\sinh(\pi Z/D)}. \qquad (18)$$

The function (18) is of rapid decrease of Z. Thus, the magnetic field splitting above the sample Eq. (16) at the distance of one-third of the period of CD structure is about $0.15\delta B/\mu_0$. It follows from Eq. (18) that the measurement of the magnetic field splitting δH_n at given distance $Z = d$ *above* the surface of the sample can give information about magnetic induction splitting δB *inside* the sample due to CD structure with given period $2D$.

The Hall probes measurements of magnetic field distribution above the sample surface [5], [15] were performed on a high quality single crystal of Ag $2.4 \times 1.6 \times 1.0\ mm^3$. The Dingle temperature was estimated to be $T_D = 0.2K$. At the conditions of the experiment, $\mu_0 H = 10T$ and $T = 1.3K$ [5], the magnetic induction splitting, calculated in LKS approximation with a Eq. (8), gives

$\delta B(1.3K)/\mu_0 = 16.7G$. These estimations are in agreement with the earlier famous NMR measurements in Ag [4], where at the slightly less favorable conditions for observation of CD structure, e. g. $\mu_0 H = 9T$, $T = 1.4K$ and $T_D = 0.8K$, the smaller value of induction splitting in the sample $\delta B/\mu_0 \approx 12G$ was reported. At the conditions of the experiment [4], the Eq. (16) with taking into account Eq. (8) gives the value of $\delta B(1.4K)/\mu_0 = 11.7G$ close to the reported one, justifying the applicability of the LKS approximation [2] for belly oscillations in Ag.

Correct treatment of the experimental results on measuring of distribution of magnetic field by Hall probe technic [5] can be done with knowledge of the ratio of the distance between the set of Hall probes and the surface of the sample d to the period of the domain structure $2D$ (see, e.g. Eq. (18)). Unfortunately, the distance between Hall probes and sample surface was not reported in [5], and there are no accurate data about the characteristic magnetic sizes of the non-uniform phase, except of the statement, that the domain period was not smaller than $150\mu m$. The more complex measurements of the magnetic field distribution at different fixed positions in the direction perpendicular to the surface of the sample would provide the lacking information about the period of the CD structure. To compare the theory with the available experimental results [5] we use the fitting parameter $d/2D \approx 0.1$, which gives reasonable value of $d \approx 15\mu m$ for $2D = 150\mu m$ within accuracy of the experiment [19]. At $d \approx 50\mu m$ which is the reasonable value for the average distance between unpolished surface and Hall probes, the calculated magnetic field splitting δH Eq. (18) is about $2.5G$, which is at the edge of accuracy of the experiment [5]. It explains the absence of the signal from Hall probes for rough surface [5]. The results of comparison of the temperature and magnetic field dependencies of the measured magnetic field distribution above the surface of the sample [5] with the value of δH_n, calculated from Eq. (18) in LKS approximation (8) are present in Fig. (7). The reported critical

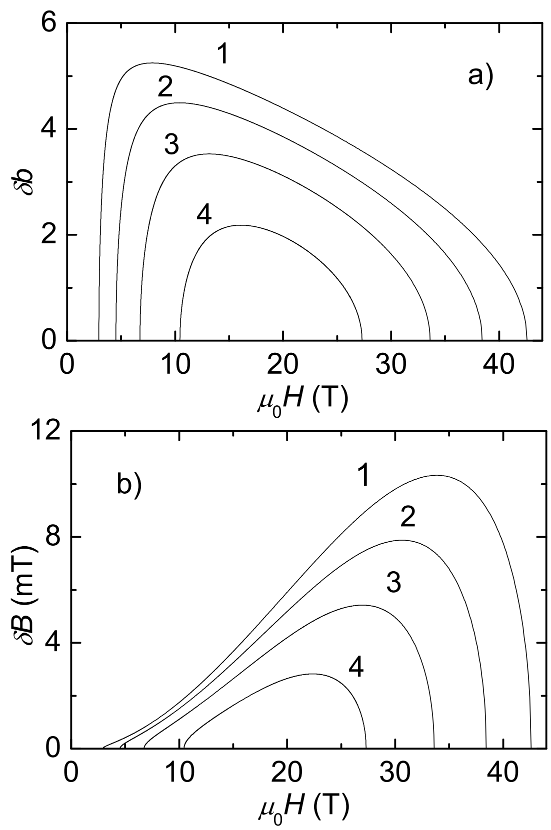

FIG. 6: Magnetic field dependence of the reduced induction splitting δb (a), caused by two adjacent domains, and corresponding measured value δB (b) in silver for $T = 1.3K$ and four different Dingle temperatures: 1 - $T_D = 0.1K$, 2 - $T_D = 0.5K$, 3 - $T_D = 0.9K$, and 4 - $T_D = 1.3K$. Similar to Fig. (5), the second power law dependence of the period of the dHvA oscillations on the applied magnetic field shifts the maximum values of measured characteristics to the high-field range.

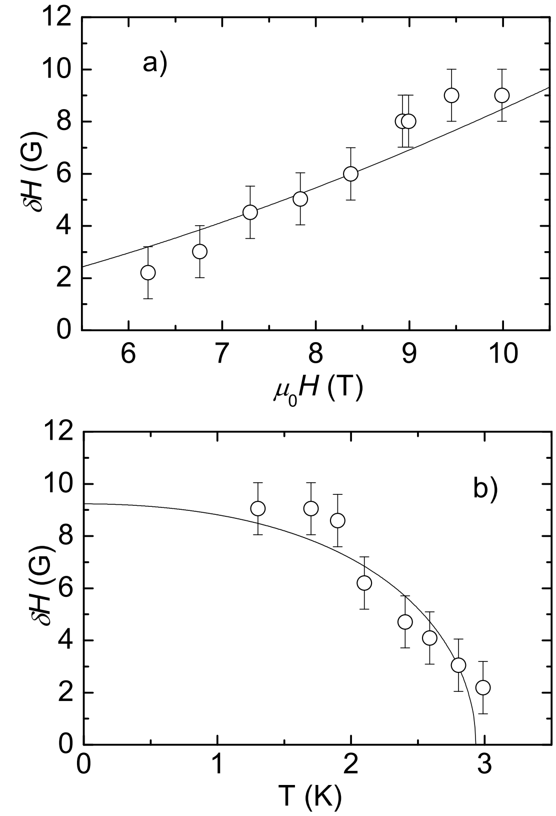

FIG. 7: Comparison between theory and experiment. (a) Applied magnetic field dependence (a) and temperature dependence (b) of the magnetic field splitting δH above the surface of the sample, caused by the induction splitting δB of CD structure. The solid lines correspond to the magnetic field distribution, calculated from Eq. (16) in the framework of LKS approximation at the conditions of the experiment [5]: $\mu_0 H = 10T$ and $T_D = 0.2K$. The circles are referred from [5]. In calculation of the theoretical curves the fitting parameter $d/2D = 0.1$ is used.

temperature $T_c \approx 3K$ at $\mu_0 H = 10T$, defined from the temperature dependence of the measured splitting, is in accordance with the predicted value $T_c = 2.9K$, calculated in LKS approximation for $T_D = 0.2K$ at the same value of $\mu_0 H = 10T$.

IV. CONCLUSIONS

We investigated theoretically the temperature and magnetic field characteristics of the CD structure in LKS approximation [1], [2]. We show that the magnetic induction splitting in non-uniform diamagnetic phase, caused by the arising instability of strongly correlated electron gas in high magnetic field and low temperature, and the range of the existence of this phase depend on temperature, magnetic field and impurity of the sample. We show that the magnetic induction splitting, e. g. the order parameter of the DPT, and the range of the existence of this phase in every dHvA period are dependent on each other functions at the wide range of magnetic field with possible existence of the non-uniform diamagnetic phase. We calculated the critical behavior of the parameters of the non-uniform phase. The theoretical results are in good agreement with available experimental data on observation of CDs in Ag. Further experiments on observation of electron instability and formation of CD structure would provide the lacking information on characteristic magnetic sizes, e. g. width of the domains.

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